

Various effective conditions can be used to electroprocess a matrix. While the following is a description of a preferred method, other protocols can be followed to achieve the same result. Referring to Figure 1 in electrospinning fibers, micropipettes 10 are filled with materials and suspended above a grounded target 11, for instance, a metal ground screen placed inside the central cylinder of the RCCS bioreactor. Although this embodiment involves two micropipettes acting as sources of materials, the present invention includes embodiments involving only one source or more than two sources. A fine wire 12 is placed in the solution to charge the solution in each pipette tip 13 to a high voltage. At a specific voltage determined for each solution and apparatus arrangement, the solution suspended in each pipette tip is directed towards the grounded target. This stream 14 of materials may form a continuous filament, for example when collagen is the material, that upon reaching the grounded target, collects and dries to form a three-dimensional, ultra thin, interconnected matrix of electroprocessed collagen fibers. Depending upon reaction conditions a single continuous filament may be formed and deposited in a non-woven matrix.

As noted above, combinations of electroprocessing techniques and substances are used in some embodiments. Referring now to Figure 2, micropipette tips 13 are each connected to micropipettes 10 that contain different materials or substances. The micropipettes are suspended above a grounded target 11. Again, fine wires 12 are used to charge the solutions. One micropipette produces a stream of collagen fibers 14. Another micropipette produces a stream of electrospun PLA fibers 16. A third micropipette produces an electroaerosol of cells 17. A fourth micropipette produces an electrospray of PLA droplets 18. Although the micropipettes are attached to the same voltage supply 15, PLA is electrosprayed rather than electrospun from the fourth micropipette due to variation in the concentration of PLA in the solutions. Alternatively, separate voltage supplies (not shown) can be attached to each micropipette to allow varying electroprocessing methods to be used through application of different voltage potentials.

Similarly, referring now to Figure 8, the same material can be applied as electrospun fibers 19 from one of the two micropipettes and electrosprayed droplets 20 from the other micropipette disposed at a different angles with respect to the grounded substrate 11. Again, the micropipette tips 13 are attached to micropipettes 10 that contain varying concentrations of materials and thus

produce different types of electroprocessed streams despite using the same voltage supply 15 through fine wires 12.

Minimal electrical current is involved in this process, and, therefore, electroprocessing, in this case electrospinning, does not denature the materials
5 that form the electroprocessed materials, because the current causes little or no temperature increase in the solutions during the procedure. In melt electrospinning, there is some temperature increase associated with the melting of the material. In such embodiments, care is exercised to assure that the materials or substances are not exposed to temperatures that will denature or otherwise
10 damage or injure them.

An electroaerosoling process can be used to produce a dense, matte-like matrix of electroprocessed droplets of material. The electroaerosoling process is a modification of the electrospinning process in that the electroaerosol process utilizes a lower concentration of matrix materials or molecules that form
15 electroprocessed materials during the procedure. Instead of producing a splay of fibers or a single filament at the charge tip of the nozzle, small droplets are formed. These droplets then travel from the charged tip to the grounded substrate to form a sponge-like matrix composed of fused droplets. In some embodiments, the droplets are less than 10 microns in diameter. In other embodiments a
20 construct composed of fibrils with droplets, like "beads on a string" may be produced. Droplets may range in size from 100 nanometers to 10 microns depending on the polymer and solvents.

As with the electrospinning process described earlier, the electroaerosol process can be carried out using various effective conditions. The same
25 apparatus that is used in the electrospinning process, for instance as shown in Figure 1, is utilized in the electroaerosol process. The differences from electrospinning include the concentration of the materials or substances that form matrix materials placed in solution in the micropipette reservoir and/or the voltage used to create the stream of droplets.

30 One of ordinary skill in the art recognizes that changes in the concentration of materials or substances in the solutions requires modification of the specific voltages to obtain the formation and streaming of droplets from the tip of a pipette.

The electroprocessing process can be manipulated to meet the specific
35 requirements for any given application of the electroprocessed compositions

made with these methods. In one embodiment, the micropipettes can be mounted on a frame that moves in the x, y and z planes with respect to the grounded substrate. The micropipettes can be mounted around a grounded substrate, for instance a tubular mandrel. In this way, the materials or molecules that form materials streamed from the micropipettes can be specifically aimed or patterned. Although the micropipettes can be moved manually, the frame onto which the micropipettes are mounted is preferably controlled by a microprocessor and a motor that allow the pattern of streaming collagen to be predetermined by a person making a specific matrix. Such microprocessors and motors are known to one of ordinary skill in the art. For instance, matrix fibers or droplets can be oriented in a specific direction, they can be layered, or they can be programmed to be completely random and not oriented.

In the electrospinning process, the stream or streams can branch out to form fibers. The degree of branching can be varied by many factors including, but not limited to, voltage, ground geometry, distance from micropipette tip to the substrate, diameter of micropipette tip, and concentration of materials or compounds that will form the electroprocessed materials. As noted, not all reaction conditions and polymers may produce a true multifilament, under some conditions a single continuous filament is produced. Materials and various combinations can also be delivered to the electric field of the system by injecting the materials into the field from a device that will cause them to aerosol. This process can be varied by many factors including, but not limited to, voltage (for example ranging from about 0 to 30,000 volts), distance from micropipette tip to the substrate (for example from 0-40 cm), the relative position of the micropipette tip and target (i.e. above, below, aside etc.), and the diameter of micropipette tip (approximately 0-2 mm). Several of these variables are well-known to those of skill in the art of electrospinning microfiber textile fabrics.

The geometry of the grounded target can be modified to produce a desired matrix. By varying the ground geometry, for instance having a planar or linear or multiple points ground, the direction of the streaming materials can be varied and customized to a particular application. For instance, a grounded target comprising a series of parallel lines can be used to orient electrospun materials in a specific direction. The grounded target can be a cylindrical mandrel whereby a tubular matrix is formed. Most preferably, the ground is a variable surface that can be controlled by a microprocessor that dictates a specific ground geometry